Development of *Aphelinus asychis* (Hymenoptera: Aphelinidae) and its susceptibility to insecticides applied to mummies of its host, the green peach aphid

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ABSTRACT

We examined the suitability of the green peach aphid, *Myzus persicae* (Sulzer), as a host for *Aphelinus asychis* Walker. The solitary parasitoid, *A. asychis* imported from France, has adapted to *M. persicae* reared on potatoes in the laboratory. Females deposited about 95 eggs over 21 d in various stages of the aphid including alates. The mean emergence was 83.3%, and the highest 92.3%. The longevity of female adult parasitoids was about 20 d. Total larval developmental time (14.5 d) was shorter than the adult longevity of females. Parasitoid larvae inside *M. persicae* mummies were less susceptible to the selective aphicide pirimicarb than to the broad spectrum chemicals, methamidophos and disulfoton. The mean daily emergence (6.1%) and cumulative emergence (73.3%) from mummies treated by pirimicarb were significantly higher than those from mummies treated by methamidophos (4.1 and 49.2%) and disulfoton (0.6 and 6.7%). The high fecundity and emergence, and reduced susceptibility of *A. asychis* to the pirimicarb show its potential as a biological control agent in integrated pest management programs for green peach aphid.

Key words: *Aphelinus asychis*, *Myzus persicae*, host suitability, chemical susceptibility

INTRODUCTION

The green peach aphid, *Myzus persicae* (Sulzer) (Homoptera: Aphididae), is one of the most potentially harmful insects in the world (Tamaki 1981) because it has become resistant to many insecticides (Wyatt 1966, Rabasse and Wyatt 1985) and is a major vector of plant diseases such as potato leaf roll virus (van Emden *et al.* 1969). Thus, the need to develop integrated control approaches is very apparent.

Biological control is central to integrated pest management (IPM) programs where the use of chemicals is minimized, or selective insecticides are preferred (Hoy 1993). It is critical in biological control to maximize the utilization of native predators in combination with potential exotic natural enemies (Flint and van den Bosch 1981), yet no specific effort has been made to introduce exotic species to control green peach aphid on field crops, nor has using biological control agents on noncrop or alternative crop plants been adequately exploited (Biever 1995). *Aphelinus asychis* Walker (Hymenoptera: Aphelinidae) was first introduced to the United States in 1955 in order to control the spotted alfalfa aphid, *Therioaphis trifolii* Monell (Clausen 1956). The Aphelinidae are solitary endophagous parasitoids primarily of aphids in the family Aphididae (Stary 1988). Adult *Aphelinus* are very small (1 mm long) and thickset; the wings are short with reduced venation, and the antennae are elbowed. Mummified aphids are black, retaining the original size and shape of the aphid, and the dorsal exit hole is ragged. Otherwise

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these parasitoids resemble the Aphidiidae in biological details such as development time and fecundity although adults live somewhat longer (Rabasse and Wyatt 1985). *Aphelinus asychis* was studied as a biological control agent against pea aphid, corn leaf aphid, yellow sugar cane aphid as well as greenbug, *Toxoptera graminum* (Rondani), (Esmaili and Wilde 1972, Raney *et al.* 1973, Cate *et al.* 1977, Bai and Mackauer 1991). Hartley (1922) noted that *A. semiflavus* Howard fed on *M. persicae*, and later Ferrière (1965) synonymized *A. semiflavus* with *A. asychis*. However, Mackauer (1968) and Raney *et al.* (1971) left the European *A. asychis* as a separate species because of differences in their host pattern and a possible differing geographic strain. Gordh (1979) also classified *A. asychis* as a different species. In this study we follow Mackauer's classification because our *A. asychis* were originally imported from France to the Northwest Biocontrol Insectary and Quarantine at Washington State University, Pullman, WA, as potential biological control agents for Russian wheat aphid, *Diuraphis noxia* (Mordvilko) (Homoptera: Aphididae).

We conducted tests to assess the potential of *A. asychis* as a biocontrol agent for the green peach aphid on Solanaceae in a closed system. In the present study, laboratory experiments evaluated the suitability of *M. persicae* as a host for *A. asychis* in terms of parasitism, the developmental time of the parasitoid larvae, longevity of the adult female *A. asychis* and percent emergence rate. In addition, susceptibility of the parasitoid larvae inside *M. persicae* mummies to various insecticides were studied.

MATERIALS AND METHODS

Rearing. A colony of holocyclic (alternating sexual and parthenogenetic generations) 'Yakima' strain *M. persicae* (from USDA-ARS, Fruit and Vegetable Research Laboratory in Yakima, WA) was maintained in Pullman, WA on radish, *Raphanus sativus* L., seedlings in 4 l glass jars. The opening of each jar was covered with nylon organdy to allow air circulation. Potatoes, cv. 'Russet Burbank', were planted in 3 l plastic pots and placed in an aluminum cage (30 x 30 x 45 cm). The cage sides were nylon organdy, and a sleeve provided access. The bottom of the cage was a metal plate. The top of the cage was covered with clear plastic for observation and for light to reach the plants. *Myzus persicae* were introduced when the plants were 30 cm high. Parasitoids were reared in the cages at 21 ± 1°C, ~45% RH, and constant light. A small amount of 15% honey solution was smeared on a piece of yellow paper (Post-it™) and placed in the upper portion of the cages to provide a supplemental carbohydrate source.

Parasitism and developmental time. Six cages were used to examine developmental time of *A. asychis* from oviposition to mummification. Each cage contained one potato plant infested with about 200 *M. persicae* in various stages that provided food and were oviposition hosts for *A. asychis*. The top of the soil in the pots and the bottom of the cage were covered by white sand to make the mummies more visible. An unmated pair of *A. asychis* newly emerged (< 1 d old) from *M. persicae* mummies on potatoes was released into each cage. Survival of *A. asychis* was checked daily and their activities observed and noted. An aspirator was used to transfer pairs of parasitoids to new cages every 24 hours. Time from oviposition to mummification and the number of mummies per cage were recorded. A camel-hair brush was used to move the blackened mummies to Petri dishes, where the duration of the mummy stage and adult emergence was recorded. A total of 12 pairs of adults and 121 offspring were observed.

Chemical susceptibility. Three insecticides commonly or experimentally applied to potatoes in Washington were used to treat black mummies (parasitized as 4th instar) on potato leaves by means of a hand-held sprayer. The applied insecticides were disulfoton (Di-syston®8, Miles Inc., Kansas City, MO), methamidophos (Monitor®4, Miles Inc.), and pirimicarb (Pirimor®50DF, Zeneca Agro Co., Wilmington, DE) at the rates of 3.36, 0.84, and 0.28 mg a.i. per 100 cm^2, respectively. Water was applied to mummies for the untreated control. Each treatment was tested on 120 *M. persicae*, with 10 mummies (7 - 8 d old after complete mummification) from each of 12 *A. asychis* pairs. After the spray dried, 10 mummies on potato leaves were placed on filter paper in each Petri dish at 21 ± 1°C, ~45% RH, and constant light. Every 24 h the number of newly emerged adults of *A. asychis* was recorded. Cumulative and average daily emergence rates from different insecticide treatments were analyzed using analysis of variance and Duncan's multiple range test to detect significant differences (PROC GLM; SAS Institute 1989).

RESULTS AND DISCUSSION

Parasitism and development time. Although we did not count the remains of aphids that had been killed by parasitoid feeding, we observed that during early adulthood, female *A. asychis* killed more aphids by feeding than by ovipositing eggs, and thus their oviposition rate was very low during this period (Fig. 1A). This is a critical period for *A. asychis* to obtain nutrition for the initiation of oogenesis, as well as for improved survival (Stary 1988). Females parasitized an average of 95 *M. persicae* (Fig. 1A), which is similar to that on greenbugs as recorded by Jackson and Eikenbary (1971). However, this is fewer than the 179 mummies/female produced on greenbugs in another study (Cate *et al.* 1973). The most mummies were observed on day 12 when a mean of 25.5 mummies/female were formed (Fig. 1B). This number is higher than the 16 mummies/female produced on greenbugs (Cate *et al.* 1973). The actual number of *M. persicae* killed by the *A. asychis* pairs must be more than the number of mummies produced by a female because both male and female *A. asychis* feed on aphids over their life span.

Adult females lived about 20 d (Table 1), which is within the range (14 - 26 d) reported for *A. asychis* females reported earlier (Zohdy and Zohdy 1976). However, the times required for mummification (3.5 d), and for emergence (11 d) were shorter than those (8 - 9.2 and 14.6 - 15.7 d, respectively) reported by Zohdy and Zohdy (1976). Compared with results of the study of *A. asychis* on greenbugs (Cate *et al.* 1977), the period of mummification is shorter but the time for emergence is longer. Different aphid hosts may affect the development time of the parasitoid. The development of the immature stages of *A. asychis* in mummified aphids may also be affected by the nutritional composition of host plants (Zohdy and Zohdy 1976). In addition, the age of aphids affects the percent of parasitoids emerging (Cate *et al.* 1977). Since the *M. persicae* used in this study were of various ages, the mean percent emergence, 83.8%, was slightly lower than those (85 - 95%) from greenbug mummies in the study by Cate *et al.* (1977). However, it was higher than those from corn leaf aphid (65 - 76%), greenbug (59 - 82%), and yellow sugarcane aphid (57 - 80%) mummies found by Raney *et al.* (1971). *A. asychis* can continue to reduce *M. persicae* populations locally because overall developmental time from oviposition to emergence (14.5 d) is shorter than the longevity (19.9 d) of the female adult. A mean emergence rate as high as 92.3% demonstrates the suitability of *M. persicae* on potato as hosts for *A. asychis*.

Susceptibility to chemical insecticides. The mean daily emergence rates of *A. asychis* from *M. persicae* mummies treated by various insecticides were significantly different (F = 32.15; df = 3, 44; $p < 0.001$) (Table 2). There was no significant difference in emergence between untreated control (6.8 %) and pirimicarb treatment (6.1%). However, the mean daily emergence of *A. asychis* from mummies treated with pirimicarb was significantly higher than from mummies treated with either methamidophos (4.1%) or disulfoton (0.6%), whose emergence rates were also significantly different from each

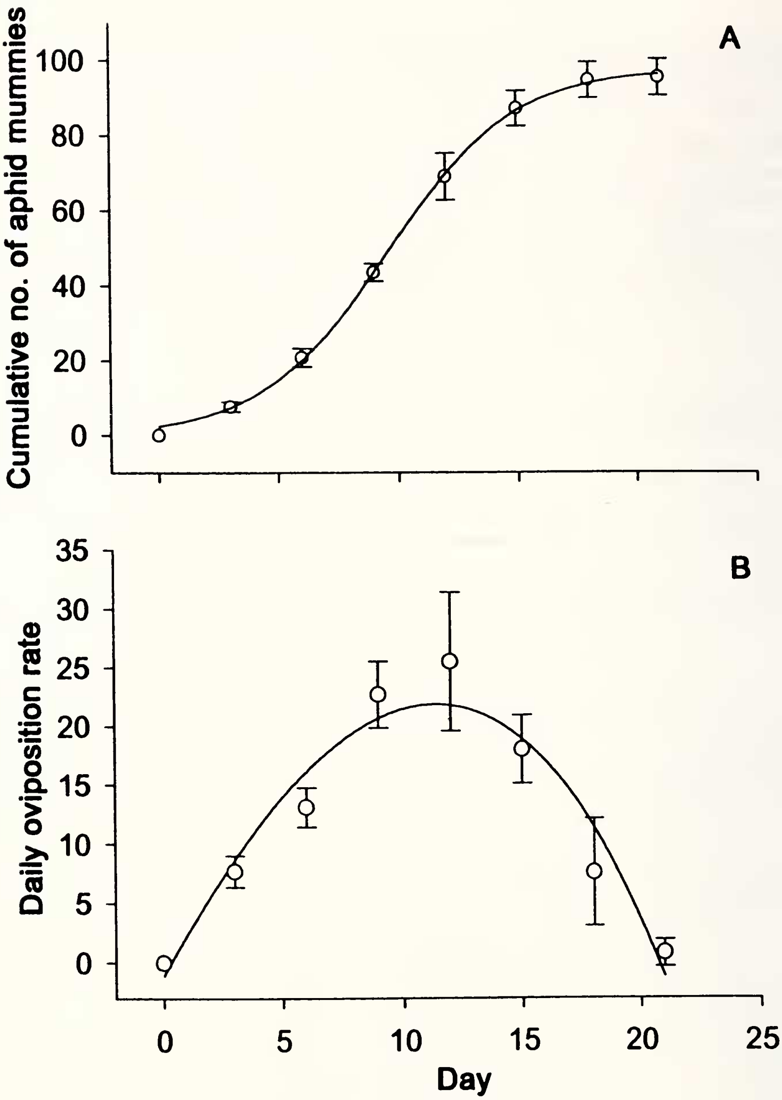

Figure 1. Cumulative numbers of aphid mummies (A) and daily oviposition rate by a pair of *Aphelinus asychis* (B). Solid lines in A and B represent nonlinear curve fits, $p<0.05$.

Table 1.

Longevity of adult females, time required for mummification and emergence, and percent emergence of *A. asychis* at 21 ± 1°C, 45% RH and continuous light. 12 females were used to determine longevity and 121 parasitoid offspring were used to determine development and emergence.

	Development time (d)			
	From oviposition to mummification	From mummification to emergence	% emergence	Longevity of female (d)
Mean ± SD	3.5 ± 0.5	11.0 ± 0.6	83.8 ± 6.3	19. 9 ± 1.1
Range	3 - 4	10 - 13	71.4 - 92.3	18 - 21

other. Cumulative emergence rates from the different insecticide treatments were also significantly different ($F = 32.15$; df = 3, 44; $p < 0.001$) (Table. 2). From pirimicarb-treated mummies, the cumulative emergence of *A. asychis* was 73.3%, not significantly different from the untreated control (81.7%) but significantly different from those treated with methamidophos (49.2%) or disulfoton (6.7%). There was also a significant difference in cumulative emergence between methamidophos and disulfoton treatments. The first emergence of *A. asychis* was observed from water-treated control mummies, followed by emergence from pirimicarb and methamidophos treated mummies. Parasitoids first emerged from disulfoton-treated mummies 6 d after treatment.

Table 2.

Daily and cumulative emergence (mean ± SD) of *A. asychis* from *M. persicae* mummies treated with disulfoton, methamidophos, and pirimicarb.

Treatment	n	Daily emergence (%)	Cumulative emergence (%)
Water control	12	6.81 ± 5.67a	81.67 ± 15.86a
Pirimicarb	12	6.11 ± 5.60a	73.33 ± 21.88a
Methamidophos	12	4.10 ± 4.17b	49.17 ± 29.68b
Disulfoton	12	0.56 ± 0.86c	6.67 ± 8.88c

Values within a column followed by the same letter are not significant ($p > 0.05$, Duncan's multiple range test, PROC GLM; SAS Institute, 1989)

There have been many studies of toxicity of insecticides to the nymphs or adults of *M. persicae*, but we are not aware of a comparative study on the effect of insecticides on *A. asychis* larvae inside *M. persicae* mummies. Although parasitoid larvae are not directly exposed to insecticides, those in newly-formed mummies may be more susceptible to insecticides than those inside older mummies. The significant differences in cumulative emergence rates showed the different degree of comparative toxicity of three insecticides to *A. asychis* inside 7 - 8 d old mummies after complete mummification. The cumulative emergence from mummies treated with the three insecticides indicate that pirimicarb is the least toxic to larvae of *A. asychis* followed by methamidophos and disulfoton. Pirimicarb controls aphids effectively with minimal effect on Aphelinid parasitoids (Helgesen and Tauber 1974, Zchori-Fein *et al.* 1994). Lecrone and Smilowitz (1980) reported that pirimicarb is less toxic than carbaryl and methamidophos to beneficial insects and more toxic to *M. persicae*. The application of pirimicarb to the aphid should help conserve natural enemies. Due to the reduced susceptibility to pirimicarb of *A. asychis* larvae inside *M. persicae* mummies, its role as a biocontrol agent in IPM programs will be improved if pirimicarb is applied during the larval development of *A. asychis*.

Potential of *Aphelinus asychis* as a biocontrol agent. Although foliar sprays of all the test insecticides (methamidophos, disulfoton, and pirimicarb) reduce the population size and probing times of *M. persicae* (Sandvol *et al.* 1980, Lowery and Boiteau 1988), early studies (Powell and Mondor 1973, Kirpes *et al.* 1982, Lowery *et al.* 1990) showed that the use of any one of these chemicals alone failed to suppress spread of potato viruses and recommended that the combined use of systemic insecticides with foliar sprays would be the most effective way to reduce virus spread. However, this would increase the control costs of *M. persicae* to twice that incurred by use of only one chemical (Kirpes *et al.* 1982). More seriously, development of resistance to pesticides by reduce the effectiveness of chemical control programs. It is becoming necessary to find control measures that are compatible with biological methods. From this point of view, integration of biological and pest-specific chemical control must be one of the strategies used to minimize problems in controlling *M. persicae*. The effective use of a selective aphicide such as pirimicarb is an essential tool for use of integrated control methods, and early innundative release of *A. asychis* should delay the growth of the *M. persicae* population.

One of the characteristics of an effective biological control agent is adaptability to a wide range of environmental conditions (Huffaker *et al.* 1971). We find that *Aphelinus asychis* have adapted well to *M. persicae* in outdoor cages in a wide range of environments, during the early spring and the summer in WA. The most successful parasitoids are those that can exploit their host without leading to its extinction (Wyatt 1985), and this parasitoid might have few natural enemies due to its "exotic" nature. The high degree of parasitism and survival of *A. asychis* larvae inside the mummies treated with the selective aphicide pirimicarb, show its potential as a good biocontrol candidate in an IPM program to control *M. persicae*.

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